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DEVELOPMENT AND STUDY OF HYBRID SOLAR AND WIND ENERGY SYSTEMS

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ABSTRACT

In the paper is about the realization of autonomous and periodic electricity supply due to the hybrid solar and wind energy system. For this purpose the hybrid system settled in Baku city and Gusar region were firstly studied in the Republic. Initially average annual solar and wind energy potentials of Baku city and Gusar region have been measured. Seperately and together average monthly and annual energy production of hybrid solar and wind energy plant were determined.

Keywords: Solar energy, Wind energy, Hybrid systems, Solar panel, Wind plant, Electricity consumption, Energy potential.

1. INTRODUCTION

One of the main indicators of each energy system is to be autonomous, continuous and reliable. Only the new techniques and technology creation does not completely solve the problem. For this purpose, according to new standards, environmental clean hybrid power systems' development from several independent sources is essential. One of the key factors in this system is more effective ways to accumulate energy. Mainly electricity is being used in each field of human life [1]. All industry sectors development is basely connected with the electricity. Electricity obtaining due to the renewable energy sources will cause the solution of the existing problems in this field [2]. Recently, in the world increaseing of the renewable energy sources usage has effective result and this warns us about the begining of the new energy era. Today the total

generation power of Azerbaijan is 6500 mW (in year $20 \cdot 10^6 \, kW \cdot hour$) [3]. 85%-electricity

generated in the Republic is obtained from thermal power stations working by natural gas and 13% of this index comes ftom the hydropower stations, 2% comes from other energy sources (personal electricity generators, wind power plants and so on) [3, 4]. Though all this energy potential in some regions there is no periodic energy provision. Majority of teh energy users utilize generators working with dizel (liquid fuel) [5]. Mainly in winter months continous fuel supply in the electric generators makes difficulties. In order to escape such problems, renewable

energy sources, solar and wind energies can be applied in hybrid systems. Hybrid solar and wind energy systems principal scheme is given in the following figure:

Figure-1. Principal Scheme of Hybrid Solar and Wind Energy System
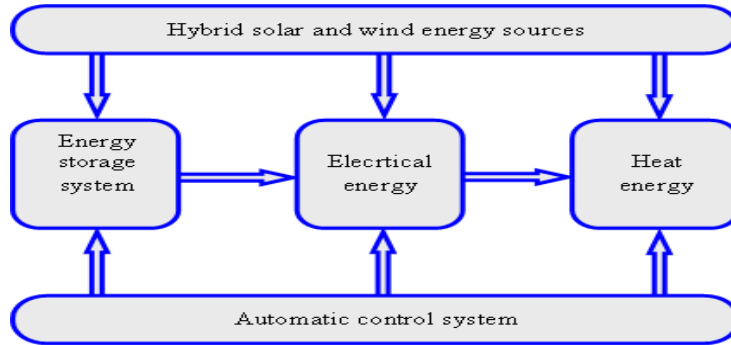
Obtaining, accumulation of thermal and electricity from solar and wind energy sources in this system is intended. Generation, accumulation and transformation of thermal and electricity is controlled by the automatic system.

Hybrid solar and wind energy systems may be applied in many fields of the industry and life [6-10]. This system supplies majorly the life goods by electricity in lightening. In some uncomfortable places, in maines' situations energy provision has great role due to the aid in electricity demand. In figure 2 the house's electricity usage is given during a month and to the hours of the day. Here, the necessary factor is the usage of the electrical goods (lightening system, refrigerator, television, water pump, computer and so on).

Figure-2. Average electricity consumption of one house during a month due to the hours of the day
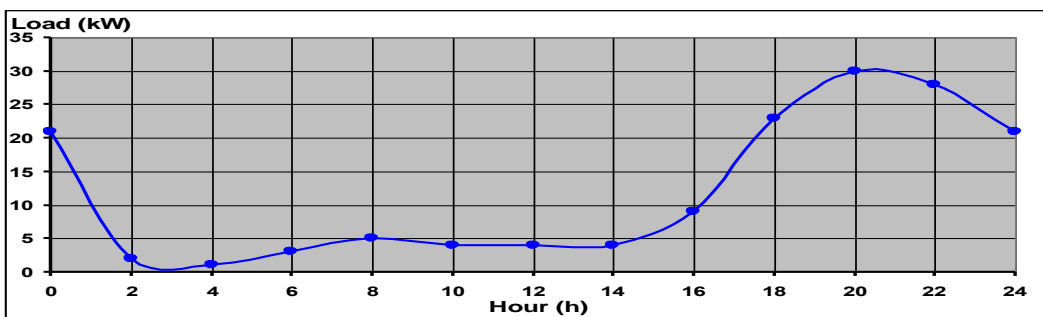
In order to generate electricity application of solar and wind energy plants depends on the climate condition [11]. Therefore solar and wind energy poentials of the region should be known in advance [12-14]. Intensity of the sun ray falling on the Earth surface and wind direction, speed change due to the weather condition and seasons [15]. If it is taken into considration that

Azerbaijan possesses rich solar and wind energy resources and each energy user can obtain the necessary power by the help of these energy sources.

Table-1. Average monthly and annual solar and wind energy potensials of Baku and Gusar region.

Region	Average energy potential												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	average annual
Soalr energy, total radiation kcal/sm²													
Baku	7,4	9,8	13,9	17,8	21.2	23,1	23,9	24,5	22,3	18,6	13,1	10,2	17,1
Gusar	2,1	2,8	3,5	5,1	5,9	6,9	8,2	8,8	8,1	6,3	4,8	3,3	5,4
Wind energy m/sec													
Baku	6,7	6,5	7,3	6,5	6,4	6,7	6,6	6,8	6,4	6,3	5,9	5,4	6,5
Gusar	2,0	2,2	2,5	2,7	2,8	2,8	2,4	2,3	2,2	2,0	2,1	2,0	2,3

At the table 1 wind speed and total solat energy potential have been given. As seen from the table both zone have too high energy potentials. From other side Gusar region is situated on the mountainous zone atmosphere air so clean here. In Gusar wind speed is weak then with Baku, windy hours of the region is about 3000 hour/year. The richest wind energy poteantial is in Baku city. As seen from the table solar energy potential in Baku equals to the potential of the places next to equator. The average wind speed consists of 6,5 m/sec for the city. As far as we knpw majority of the wind energy plants start to work at 3 m/sec speed [16-18].

By this purpose, autonomous, ecological clean hybrid solar and wind energy system was developed and tested [19]. The plant having hybrid system have been built in Baku city and Gusar region. Principal scheme of the system has been given at figure 3.

Figure-3. The General scheme of hybrid solar and wind energy plant
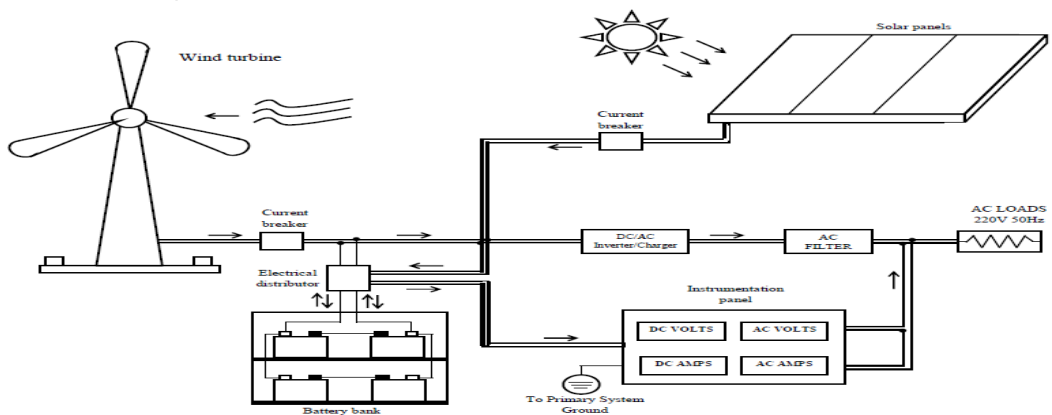
Each essencial element of solar and wind energy system has been seperatelt looked through:

2. SOLAR ENERGY SYSTEM

The main components of solar energy system are looked through:

❖ **Solar Panels**

Application of solar panels has some advantages. Thus, solar panels don't possess any mechanical and movable working part and they are resistable for each climate condition. While generating electricity from solar panels none of the waste, noice, polution happen. It has long-term work ability. At present 12 solar panels are being applied in the system which each possesses 100 W.

Figure-4. The general view of the solar panels, ((a) – in Baku city, (b) – in Gusar region).

(a)   **(b)**

• **Power Calculation of Solar Panels**

The power (W) of solar panels can be calculated as follows [20]:

$$N_{s.p} = \frac{n \cdot P_{max}}{1000} \qquad (1)$$

Here, n is amount of the solar panels (piece);

P_{max} is maximal power of solar panels (W).

The power of electricity generated from the solar panels at several solar radiations may be determined by the help of the next formular:

$$N_{s.p} = \frac{n \cdot P_{max} \cdot Q}{10^6} \qquad (2)$$

Here, Q - total solar radiation (W/m²).

❖ **Controller**

Controller is for energy coming to solar panels and discharging (charging) of the accumulators. Here, Wellsee WS C2450 controller is used. This controller has indicator for controlling the work regime of the solar panel.

Figure-5. The general view of the controller

❖ **Accumulator System**

Accumulator is for dinamic and constant transformation of energy to the user. Accumulator system has 24 W, 350 A parameters, containing of 8 accumulators with lithium ion content. The amount and the power of the accumulators were determined on the base of demanded energy potential. In order to decrease the temperature increment, fan system was set up.

Figure-6. The general view of the accumulator system

❖ **Constant/ Alternating Current Transformer**

Both electricity from solar panels and wind energy plants is the constant current source, it should be changed into altering current. For this constant/ alternating current transformer is utilized. In this system constant/ alternating current transformer with Universal Out Back Power mark was used. This transformer possesses some advantages.

- Saves from the addtional charging;
- Joins to the sytem automatically;
- Ptotects accumulators;
- Controls the chanrging system;
- Controls the consumption of the user;
- Turns off autonomically when abridgement happens.

Figure–7. The general view of constant/ alternating current transformer.

❖ **Additional Auxiliary Equipments**

Electrical keys, alternating current filter, electricity distributor, electrcity equipments panel, different type cables and others concern to the additional auxiliary equipments.

3. WIND ENERGY SYSTEM

The main components of the wind energy system are looked through:

❖ **The Trunk of the Wind Energy Plant**

The trunk of the wind plant wan belt to the concrete foundation, it consits of steel pipe and stands in the vertical position. To incease the resistans of the trunk, it is firmed in 3 points by the ropes.

❖ **Wind Energy Generator**

Generator is for transformation of the rotating movement to the electrical energy. At present work the wind plant having 2 kW nominal power was used.

❖ **Wind Plant Blade**

Wind plant blade has 3 wings and were made from the light material and has high aerodynamic showings.

Figure–8. The general view of wind energy plant

- **Calculation of the Wind Energy Plant Power**

Wind energy plant power (kW) is determined as [21]:

$$N_{w.p} = \frac{\rho}{2} \cdot F \cdot \upsilon_p{}^3 \cdot c_p \cdot \eta_r \cdot \eta_g \cdot 10^{-3} \qquad (3)$$

here, $\rho = 1{,}205 kg/m^3$ - air density,

$F = \dfrac{\pi D^2}{4}$ - square of the wind plant wheel;

$\upsilon_p, m/\sec$ - calculated wind speed;

$c_p = 0{,}45$ - wind energy use coefficient;

$\eta_r = 0{,}92$ - Efficiency of reducer;

$\eta_g = 0{,}96$ - efficiency of generator.

Due to this formular wind plant power is calculated for various wind speeds and correspondingly, $N_{w.p} = f(\upsilon)$ dependence can be made.
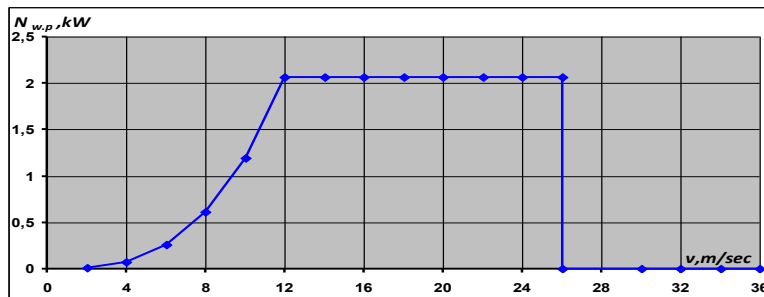
Figure-9. Power characteristics of the wind energy plant

Table-2. Dependence of wind plant power on the wind speed

$\upsilon_p, m/\sec$	**2**	**4**	**6**	**8**	**10**	**12**
$N_{w.p}, kW$	0,0095	0,0766	0,2586	0,613	1,1972	2,0689
$\upsilon_p, m/\sec$	14	16	18	20	22	24
$N_{w.p}, kW$	2,0689	2,0689	2,0689	2,0689	2,0689	2,0689
$\upsilon_p, m/\sec$	26	28	30	32	34	36
$N_{w.p}, kW$	2,0689	0,000	0,000	0,000	0,000	0,000

4. CALCULATION OF THE ELECTRICITY OF THE HYBRID SOLAR AND WIND ENERGY PLANT

To calculate amount fo the electricity generated from the hybrid system monthly energy potential for both energy resources should be known [22]. By this way, the energy generated in both sources has be accumulated together, the total annual energy generation may be determined. According to the generated electricity each source is to be clasified seperately:

- **Annual Electricity Generation of the Wind Energy Plant**

To calculate the annual generated electricity power characteristics of the wind plant and differencial repetition of wind speed are to be defined. For this the following equation is used.

$$t_i(\upsilon_i), i = 1...n \qquad (4)$$

Average wind speed indexes given at table 2 can be calculated due to the wind plant height (H) by the following formular:

$$\upsilon_H = \upsilon_h \left(\frac{H}{h} \right)^m \qquad (5)$$

here, $m = 0,6(\upsilon)^{-0,77}$

υ_h - average wind speed at the height (H) where wind vane stands,

$t_i(\upsilon_i)$ mark depending on (γ) parameter, Weibull distribution is for the mark.

From the wind plant power charcteristics is clear that between $\upsilon_H \geq \upsilon_i \geq \upsilon_{max}$ wind speed rang

its power is $N_{w.p} = 0$.

Seperatly wind plant electrical energy generation amount on each month and year is determined:

$$W_{w.p}^{month} = \sum_{i=2}^{k} N_{w.p} \cdot \upsilon_i \cdot t(\upsilon_i) \cdot T_{month} \qquad (6)$$

Here, T_{month} - hours amount on each month.

$$W_{w.p}^{year} = \sum_{i=2}^{k} W_{w.p}^{month} \qquad (7)$$

or

$$W_{w.p}^{month} = \sum_{i=2}^{k} N_{w.p} \cdot \upsilon_i \cdot t(\upsilon_i) \cdot T_{year} \qquad (8)$$

here, $T_{year} = 365 \cdot 24 = 8760 hour$

- **Annual and Monthly Electrical Energy Generation of Solar Panels.**

Electrical energy generation of the solar panels is deterined by:

$$E_{s.p} = K_t \cdot T_{day} \cdot P_{\max} \tag{9}$$

here K_t-transformation coefficient of the energy, $K_t = 0,55$

$T_{day} = \dfrac{E_{total}}{P_{day.\max}}$ - peak hours of the solar radiation.

$P_{day.\max} = 1000W/m^2$ - maximum solar radiation in the natural standard climate condition.

E_{total}- general average total energetic shining on the surface.

As the result of the calculation cariied out, mopnthly and annual graphical dependence of the electricity generated from both wind plant and solar panels may be defined:

Table-3. Average and annual energy generation of complete hybrid system and solar panels and wind plant.

Energy plant	Unit	Months												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Wind plant	kW	355,4	378,6	402,1	381,6	418,8	400,6	344,9	348,2	370,2	358,7	321,3	298,9	4379,3
Solar panel	kW	26,3	38,7	74,4	130,6	181,5	224,6	232,4	230,5	198,8	112,6	71,1	34,7	1556,2
Hybrid system	kW	381,7	417,3	476,8	512,2	600,3	625,2	577,3	578,7	569	471,3	392,4	333,6	5935,5
Percentage index of energy production of hybrid system														
Wind plant	%	0,93	0,9	0,84	0,74	0,69	0,64	0,59	0,6	0,65	0,76	0,81	0,89	-
Solar panel	%	0,07	0,1	0,16	0,26	0,31	0,36	0,41	0,4	0,35	0,24	0,19	0,11	-

Due to indexed shown at table 3 in the energy generation by the commmbined energy system wind plant percentage consists of 0,753 %, solar panels' is 0,247%.

Figure-10. Here 1 – annual electricy amount generated from the wind plant, 2 – annual electricy amount generated from solar panels.
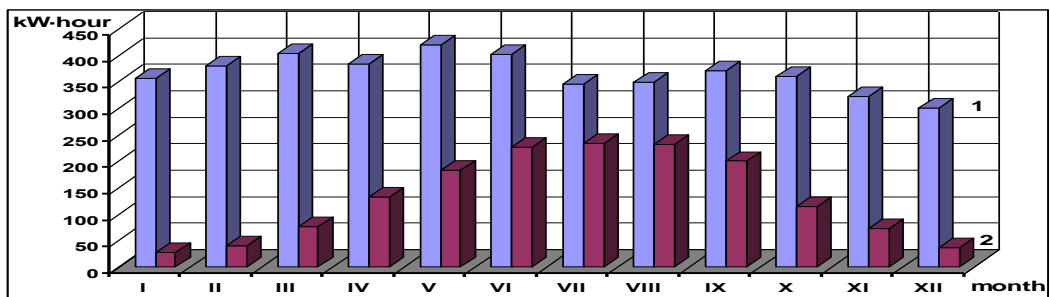
5. ECONOMICAL ANALYSIS

Due to indexed shown at table 2 annually average electricity generation from wind plant is 4380 kW, and from solar panels is 1556 kW, in the general hybrid system 5936 kW electricity is generated. At present the sale price of electricity is 0,06 AZN (0,076 USD) (1 USD=0,78 AZN) annual economical efficiency of the hybrid system will be 356 AZN (452 USD). The total price of the experimental plant is 5000 AZN (6410 USD). So, the investigation will come back after 14 years. Exploitaition term of the plant consists of $20-25$ years.

6. CONCLUSIONS AND RESULTS

I should mention that the developed hybrid solar and wind energy plant is the first system for investigation and testing in Azerbaijan. Though it is the initial one, the results are suitable to the conclusions obtained from the other systems existing in the world. Development of such systems aressupported by the State Program (The work was firstly realized within the state program on application of alternative and renewable energy sources in Azerbaijan which was signed in October 21, 2004.) of Azerbaijan.

7. ACKNOWLEDGEMENTS

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